PEER

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Resilience
Next Generation PBEE?

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Outline

- Where we have come since 2011
  - How social science, government and NGOs have adopted the resilience concept
- Examples of Engineering Adaption
  - Performance Based Integration of Social Resilience Metrics
  - Advanced Risk Modeling for Resilience
- Future Work for PEER Researchers

Two Paradigms on Resilience*

- **Engineering Resilience** focuses on efficiency, constancy, predictability
  - Defined as stability near an equilibrium or steady state
- **Ecological Resilience** focuses on persistence, change, unpredictability
  - Defined as the capacity of a system to absorb disturbance and reorganize while undergoing change

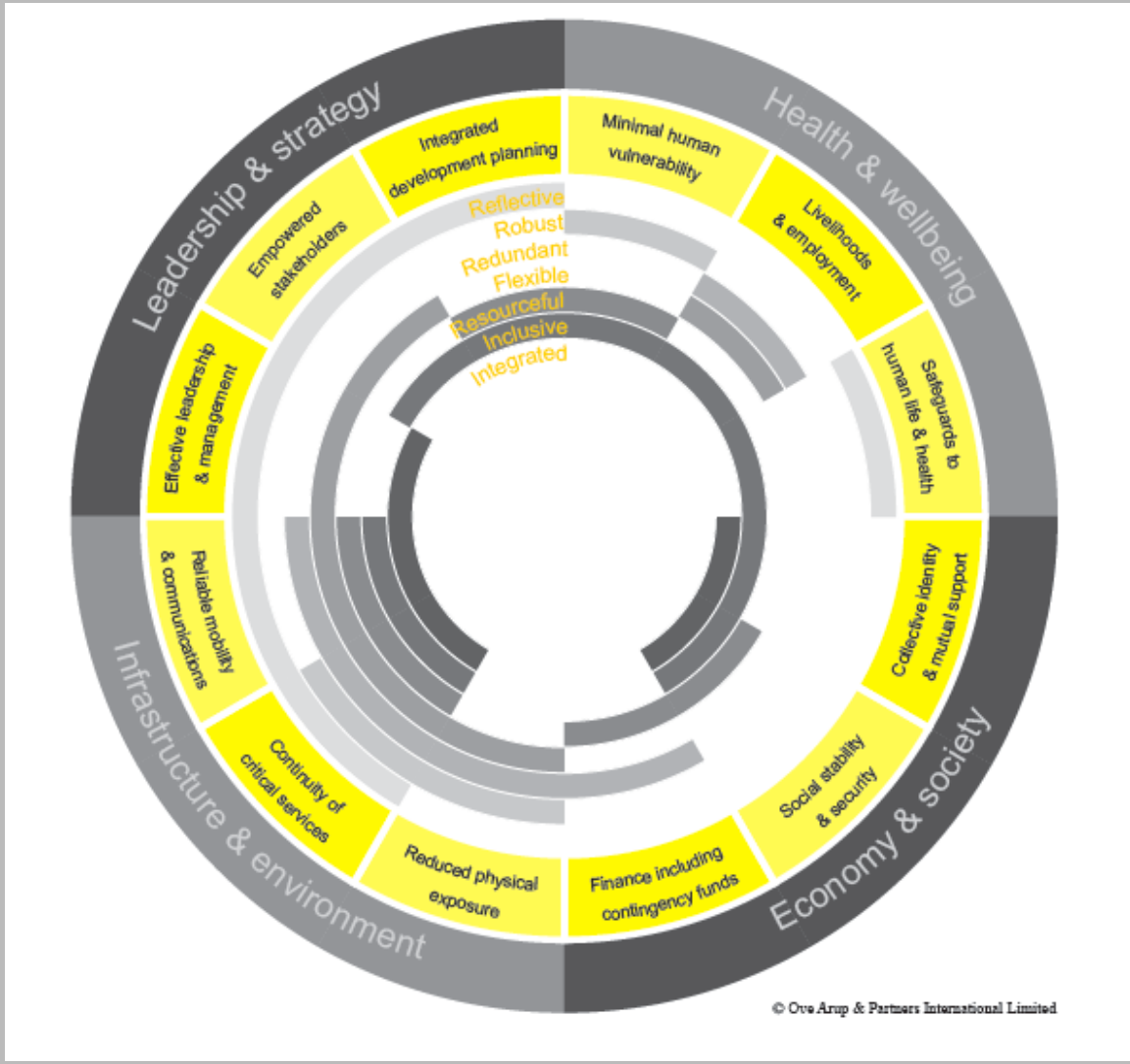
*C.S. Holling, 2009; C. Folke, 2006 and others

Urban Resilience: Multi-faceted

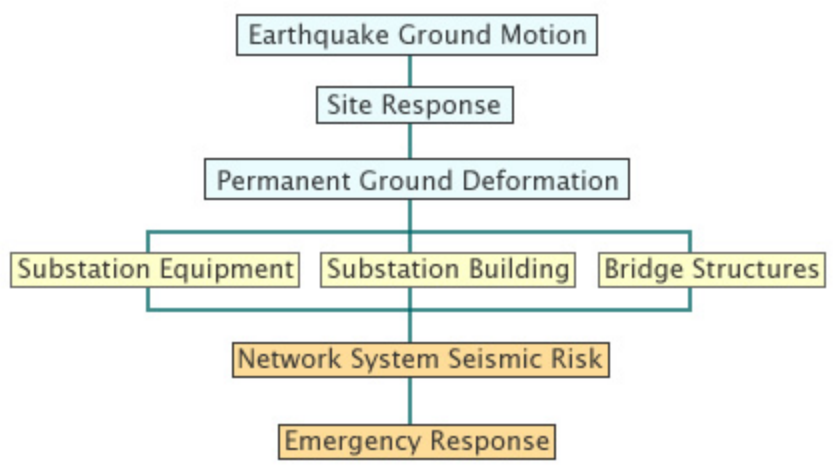
The capacity of communities to survive, adapt and grow, now matter what kind of chronic stress or acute shock they experience.

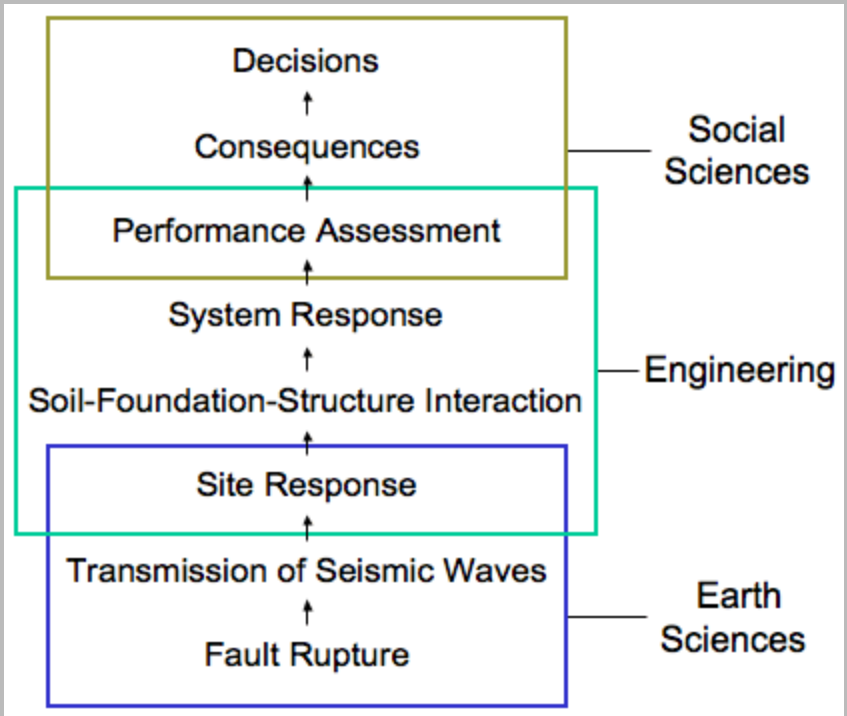
Rockefeller Foundation
100 Resilient Cities
Framework with
12 Indicators
150Variables

Dimensions: Social, Economic, Institutional, Infrastructural, Ecological, Community



Application to PEER Research



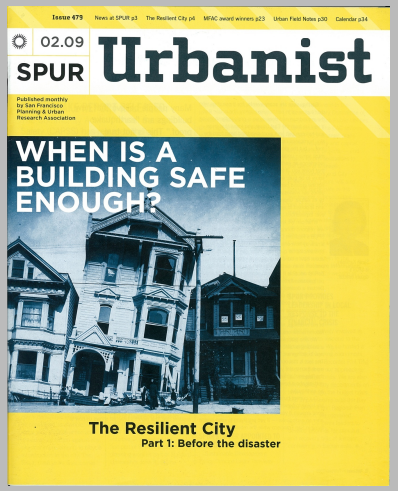


-PBEE is a giant step past prescriptive building codes to targeted performance goals

- Next step to go beyond building/infrastructure design and look at cascading consequences for users/communities

SPUR Resilient City Approach

- Define concept of ***resilience*** for disaster recovery
- Establish ***performance goals*** for a M 7.2 earthquake
- Define transparent ***performance measures***
- Recommended ***target states of recovery*** for San Francisco's new buildings, existing buildings and lifelines



TARGET STATES OF RECOVERY FOR SAN FRANCISCO'S BUILDINGS AND INFRASTRUCTURE

INFRASTRUCTURE CLUSTER FACILITIES	Event occurs	Phase 1 Hours			Phase 2 Days		Phase 3 Months		
		4	24	72	30	60	4	36	36+
COMMUNITY RECOVERY									
All residences repaired, replaced or relocated							■		×
95% neighboorhood retail businesses open							■	×	
50% offices and workplaces open							■		×
Non-emergency city service facilities								×	

TARGET STATES OF RECOVERY

Performance measure	Description of usability after expected event	
	BUILDINGS	LIFELINES
	Category A: Safe and operational	
	Category B: Safe and usable during repairs	100% restored in 4 hours
	Category C: Safe and usable after moderate repairs	100% restored in 4 months
	Category D: Safe and usable after major repairs	100% restored in 3 years
×	Expected current status	

Note: Categories A–D are defined on page 10.

Steps to Community Resilience

Critical to Recovery
Jobs and Business
Utilities
Tourism/Hospitality
Business Services

Shelter and Housing
CAPSS estimates M7.2 EQ
25% of housing not habitable
(85,000 units)
2/3s are 3+ unit wood soft story
If retrofit, could reduce uninhabitable units to 8-10%

Resilience Goal 95% can shelter in place in 30 years

San Francisco's Planning Efforts

- **Citywide Post Disaster Resilience and Recovery Initiative**
- Local Lifeline Council of major utilities to explore interdependencies and restoration strategies,
- Post-disaster governance project,
- Appointment of a Chief Resilience Officer
- Financial planning, enterprise risk management, planning for small and medium-sized businesses, economic impact analysis,
- Long-term housing plan, plus retrofit of soft-story apts.
- Coordination with regional and federal recovery efforts

How to Integrate into a Research Platform

- As with Loss Modeling (e.g. HAZUS), use default data or develop locally specific data and metrics.
- Social metrics (health, housing, employment, economics, environment) are data driven and use discipline-specific models for analysis, but…
- Link models to building/infrastructure inventory data for community/regional impacts of proposed policies.

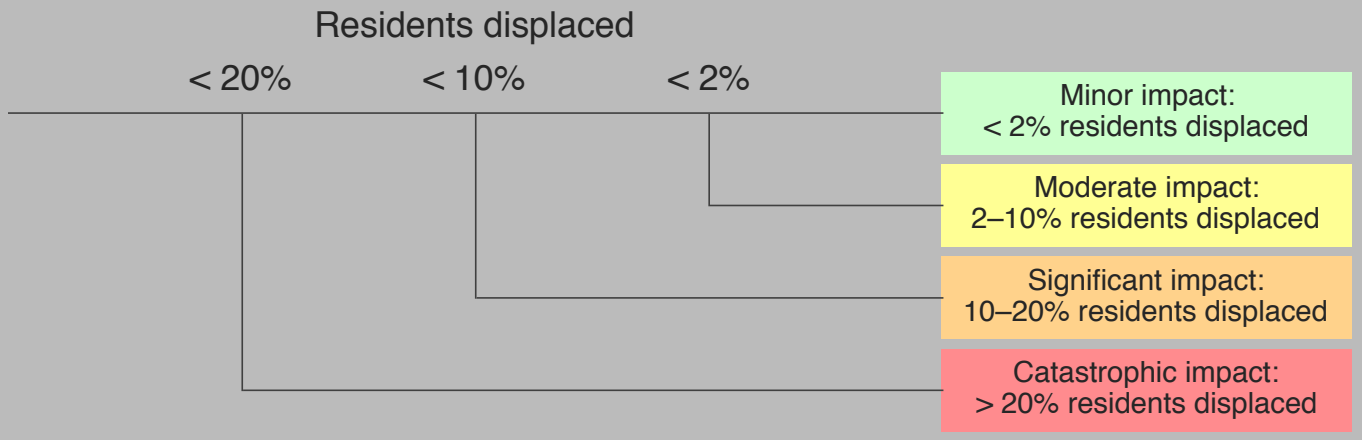
Linking Community Resilience Goals to Performance Objectives

1. Define key system parameters:
   - Undesired outcome(s)
   - *e.g. significant outmigration*
   - Vital community function(s)
   - *e.g. housing, public services ,employment, education*
2. Establish community-level resilience goal(s)
   - *< 1% probability of significant outmigration in 500-yr EQ*

Mike Mieler Dissertation, UCB, 2013

Extending PBEE, Con't

3. Establish performance objectives for vital community functions
   - *For each vital community function, construct an "event tree" that captures the range of possible outcomes after an EQ*
   - *Based on Event Tree Analysis, Use the mean for a 500 yr EQ*



Mike Mieler Dissertation, UCB, 2013

Extending PBEE, Con't.

4. Establish performance targets for important systems and components
   - Residents displaced only if homes do not achieve "shelter-in-place" performance
   - % of residents displaced ≈ % of buildings not safe to occupy
   - *Performance Target for Housing stock: < 4.9% of housing stock not safe to occupy.*

   APPLICATIONS
   - *Verify whether building codes consistent w/ resil. goals*
   - *Develop performance standards for Lifelines*

Mike Mieler Dissertation, UCB, 2013

Modeling Risk/Growth Trajectory

- By 2030: ~60% of world population will be urban
  - The add-hoc process of incremental construction is the default and most prevalent form of urban construction.

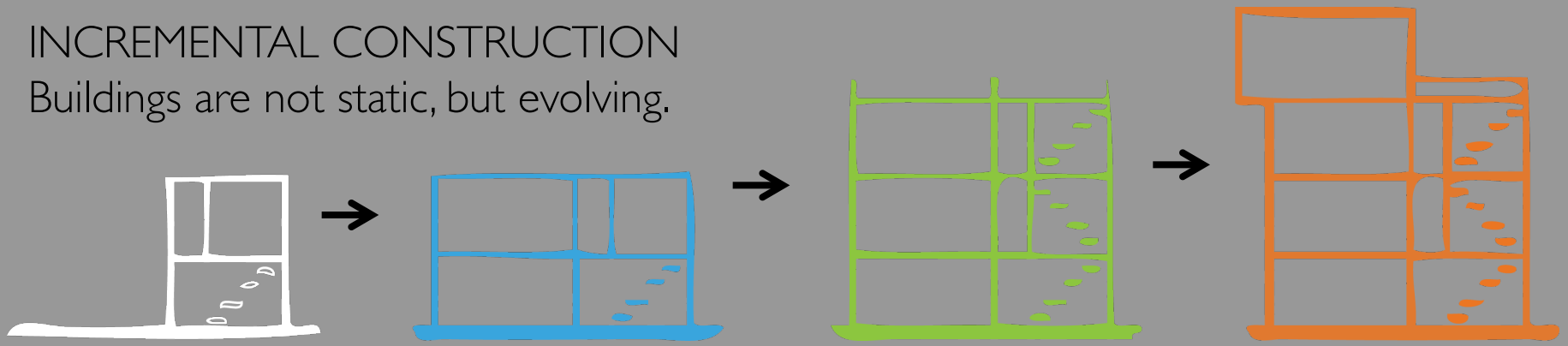
David Lallemant Dissertation, Stanford, 2015

Julia King, "Incremental Cities"

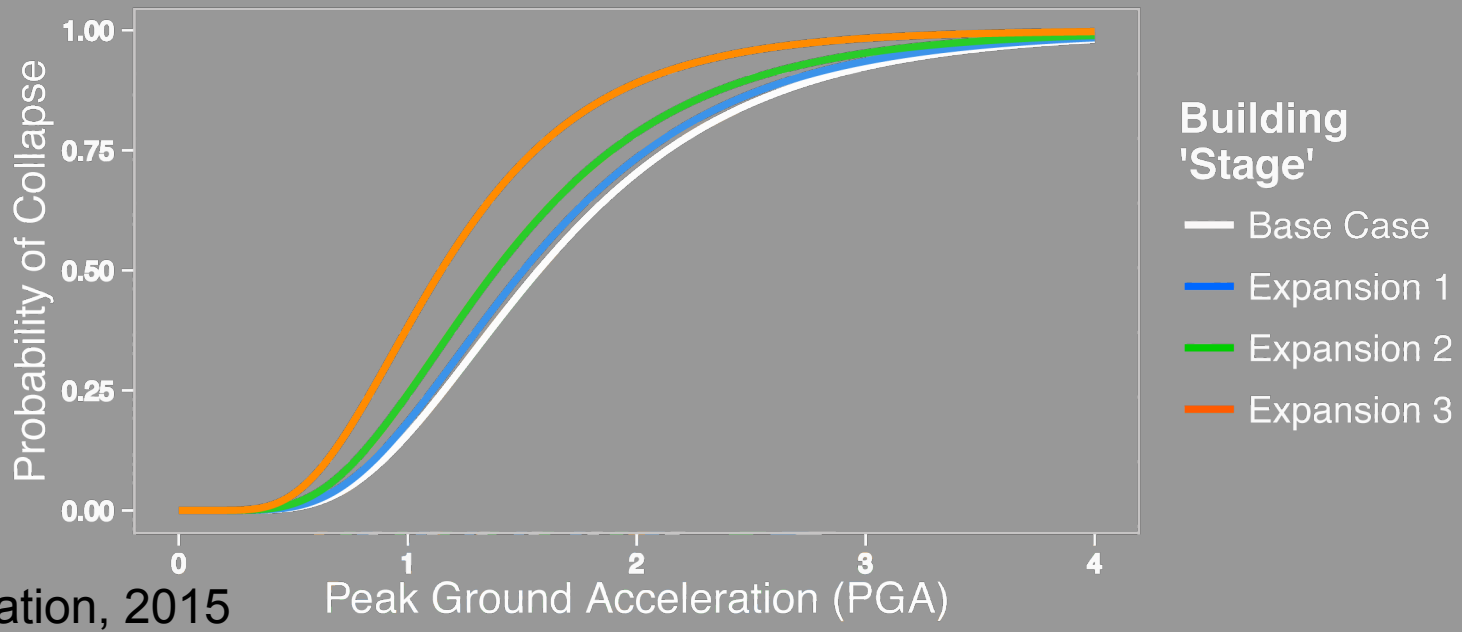
Dynamic Vulnerability

INCREMENTAL CONSTRUCTION

Buildings are not static, but evolving.



What does this mean for building vulnerability?



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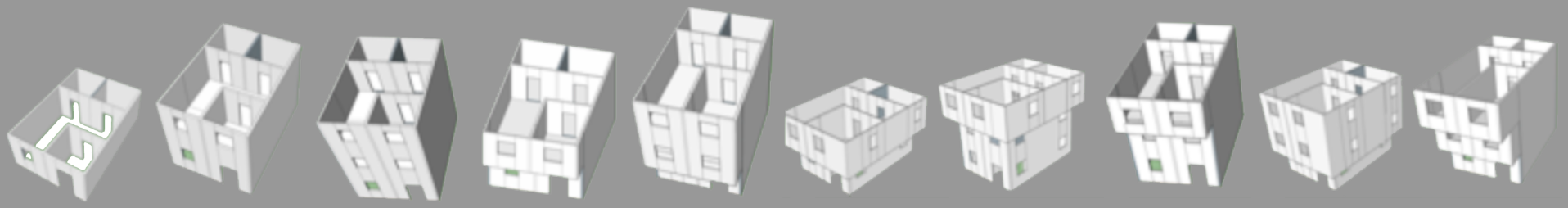
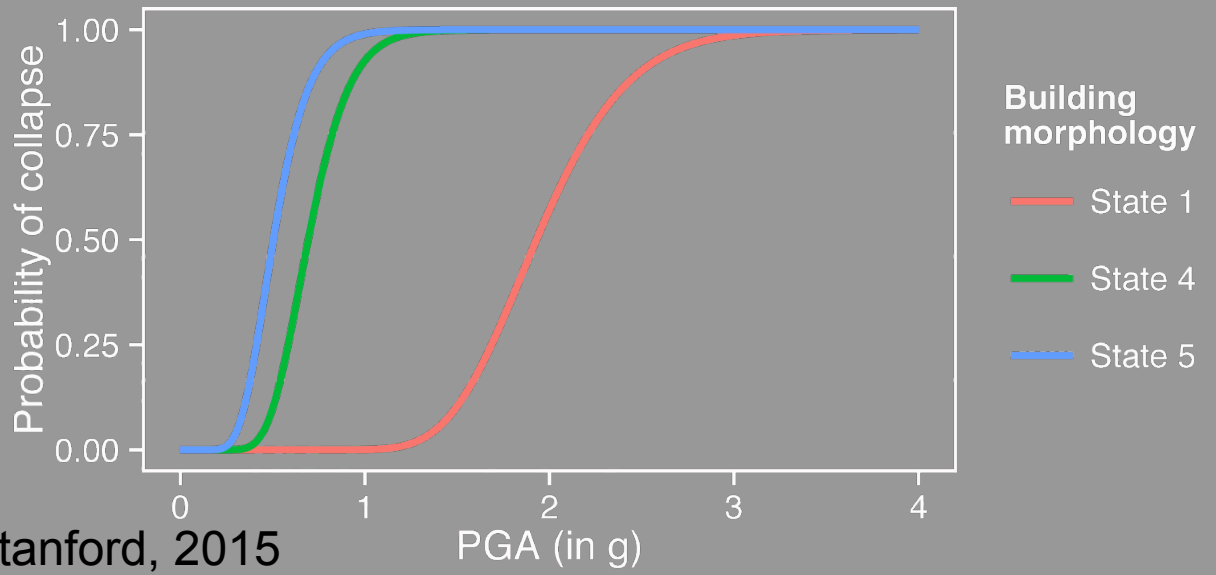
Modeling Dynamic Vulnerability

Catalog common building expansion states:



Fragility model associated with every building state.



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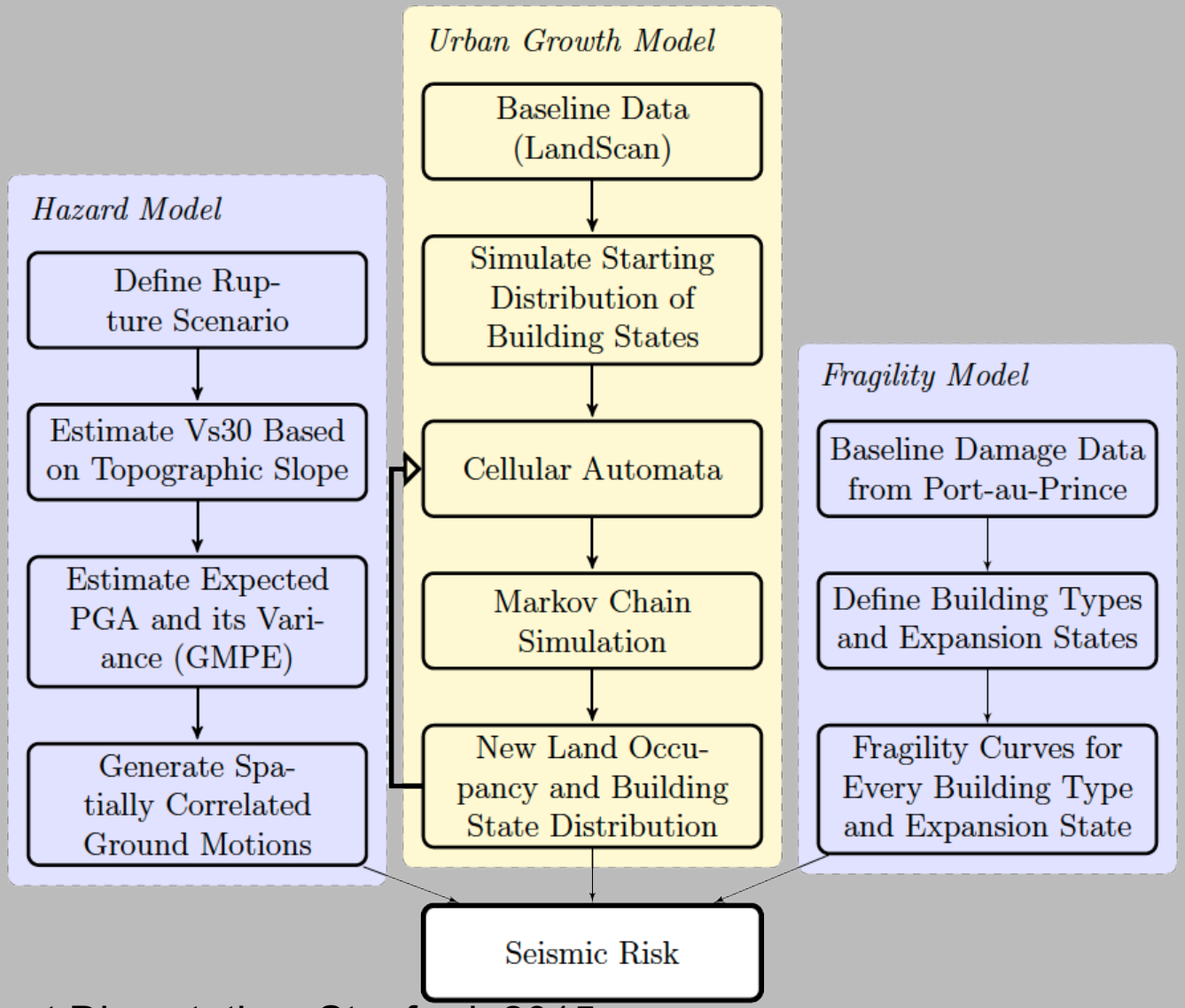
Time-dependent Urban Risk Model Diagram



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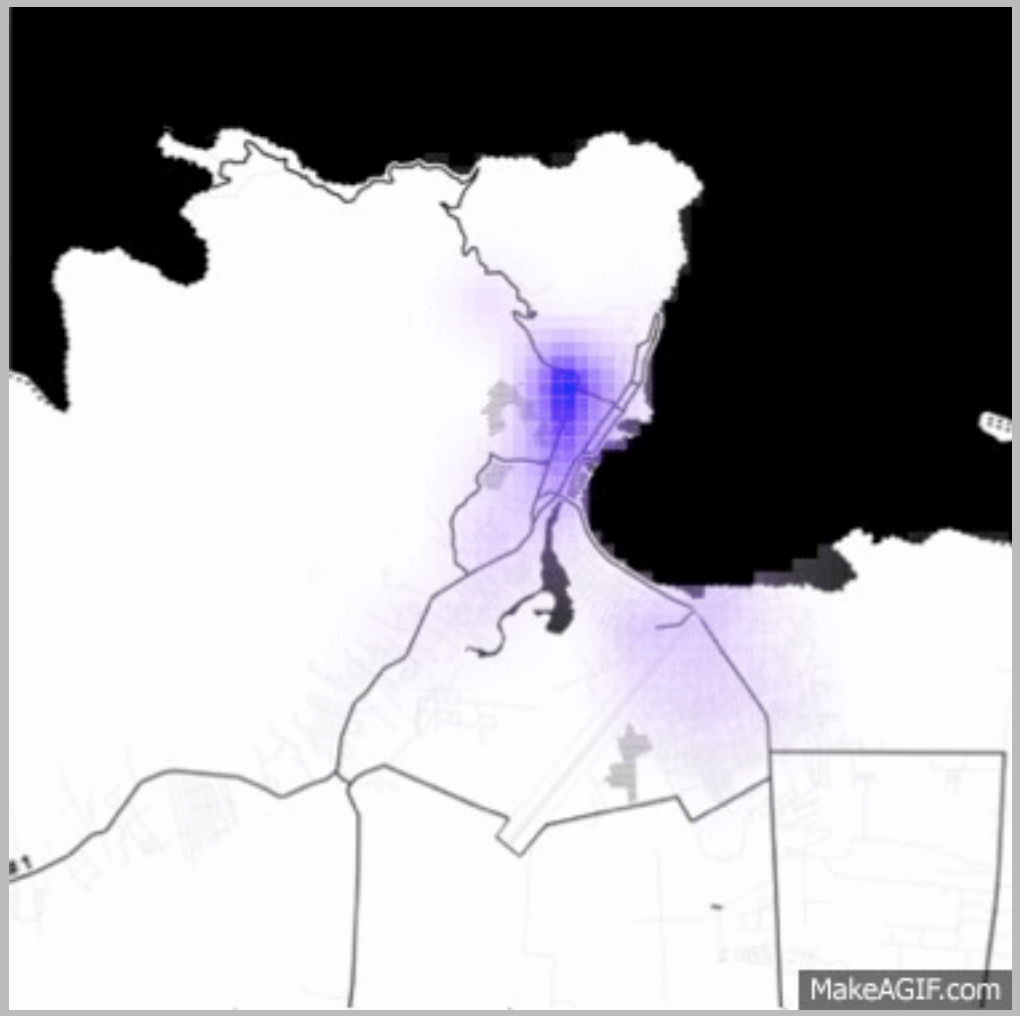
Cap-Haitien Urban Growth Model



Model calibrated from LandSat data for years 2010-2013

Years 2013 – 2020 – 2030 – 2040 - 2050

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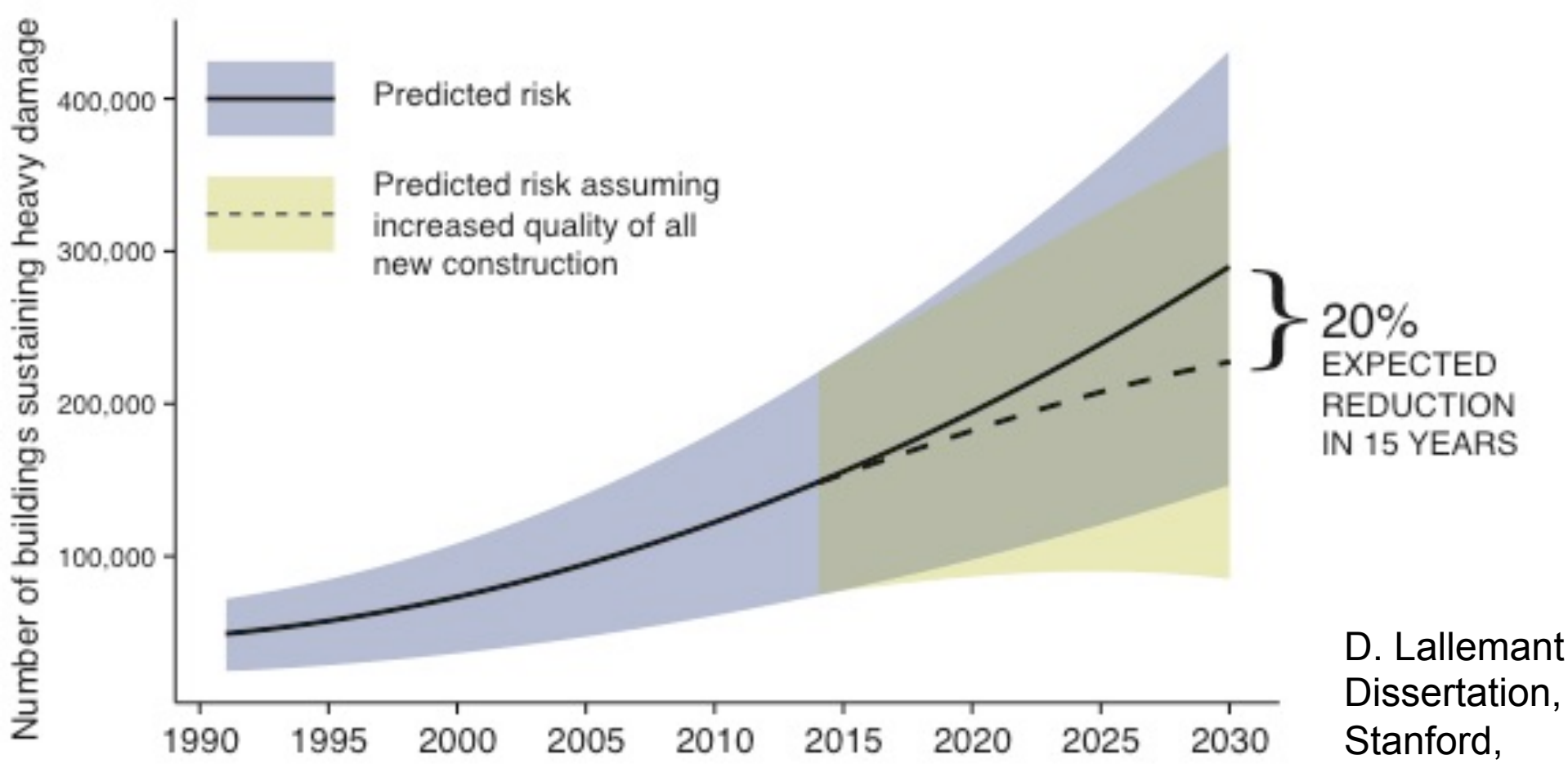
Controlling Evolving Seismic Risk

What if all new construction is better designed for



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Conclusion

- Analytic methods can be developed to build engineering applications for resilient and sustainable cities.
- Research opportunities to extend PBEE and Risk Models to quantify resilience.
- Next Generation PBEE is inventory/data driven integrating models from other fields.